

CLAIMS

1. Steel plate for ultra-high-strength linepipe having excellent low-temperature toughness consisting of:

5 C : 0.03 to 0.07 mass%
 Si : not more than 0.6 mass%
 Mn : 1.5 to 2.5 mass%
 P : not more than 0.015 mass%
 S : not more than 0.003 mass%
 Mo : 0.15 to 0.60 mass%
 10 Nb : 0.01 to 0.10 mass%
 Ti : 0.005 to 0.030 mass%
 Al : not more than 0.10 mass%

and, one or more of:

15 Ni : 0.1 to 1.5 mass%
 B : less than 3 ppm
 V : not more than 0.10 mass%
 Cu : not more than 1.0 mass%
 Cr : not more than 1.0 mass%
 Ca : not more than 0.01 mass%
 20 REM : not more than 0.02 mass%
 Mg : not more than 0.006 mass%

and the remainder consisting of iron and unavoidable impurities and having the value P defined below being between 2.5 and 4.0, in which;

25 the ratio $(Hv-ave_p)/(Hv-M)$ between the average Vickers hardness $Hv-ave_p$ in the direction of thickness and the martensitic hardness $Hv-M$ determined by carbon content is between 0.8 and 0.9, and the transverse tensile strength $TS-T_p$ is between 880 MPa and 1080 MPa,

30
$$P = 2.7C + 0.4Si + Mn + 0.8Cr + 0.45(Ni + Cu) + Mo - 1$$

$$Hv-M = 270 + 1300C$$

wherein the symbols of elements designate the mass% of the individual elements.

35 2. Steel plate for ultra-high-strength linepipe having excellent low-temperature toughness consisting of:

C : 0.03 to 0.07 mass%

	Si	: not more than 0.6 mass%
	Mn	: 1.5 to 2.5 mass%
	P	: not more than 0.015 mass%
	S	: not more than 0.003 mass%
5	Mo	: 0.15 to 0.60 mass%
	Nb	: 0.01 to 0.10 mass%
	Ti	: 0.005 to 0.030 mass%
	Al	: not more than 0.10 mass%
	B	: 3 ppm to 0.0025 mass%
10	and, one or more of:	
	Ni	: 0.1 to 1.5 mass%
	N	: 0.001 to 0.006 mass%
	V	: not more than 0.10 mass%
	Cu	: not more than 1.0 mass%
15	Cr	: not more than 1.0 mass%
	Ca	: not more than 0.01 mass%
	REM	: not more than 0.02 mass%
	Mg	: not more than 0.006 mass%

and the remainder consisting of iron and unavoidable
 20 impurities and having the value P defined below being
 between 2.5 and 4.0, in which;
 the ratio $(Hv-ave_p)/(Hv-M)$ between the average Vickers
 hardness $Hv-ave_p$ in the direction of thickness and the
 martensitic hardness $Hv-M$ determined by carbon content is
 25 between 0.8 and 0.9, and the transverse tensile strength
 $TS-T_p$ is between 880 MPa and 1080 MPa,

$$P = 2.7C + 0.4Si + Mn + 0.8Cr + 0.45(Ni + Cu) + 2Mo$$

$$Hv-M = 270 + 1300C$$

30 wherein the symbols of elements designate the mass%
 of the individual elements.

3. Steel plate for ultra-high-strength linepipe
 having excellent low-temperature toughness described in
 claim 1 or 2, containing:

35 N : 0.001 to 0.006 mass%.

4. Steel plate for ultra-high-strength linepipe
 having excellent low-temperature toughness described in

claim 3, in which the relationship $T_i - 3.4 N > 0$ is satisfied (wherein the symbols of elements designate the mass% of the individual elements).

5 5. Steel plate for ultra-high-strength linepipe having excellent low-temperature toughness described in any of claims 1 to 4, in which the V-notch Charpy value at $-20\text{ }^{\circ}\text{C}$ is not lower than 200J.

10 6. Steel plate for ultra-high-strength linepipe having excellent low-temperature toughness described in any of claims 1 to 5, in which the longitudinal tensile strength $TS-L_p$ is not greater than 0.95 times the transverse tensile strength $TS-T_p$.

15 7. Steel plate for ultra-high-strength linepipe having excellent low-temperature toughness described in any of claims 1 to 6, in which the yield ratio in the direction of rolling $(YS - L_p)/(TS - L_p)$, which is the ratio of the 0.2% offset yield strength $YS - L_p$ in the direction of rolling to the tensile strength $TS - L_p$ in the direction of rolling is not greater than 0.8.

20 8. Ultra-high-strength linepipe having excellent low-temperature toughness prepared by seam-welding steel plate consisting of:

	C	: 0.03 to 0.07 mass%
	Si	: not more than 0.6 mass%
25	Mn	: 1.5 to 2.5 mass%
	P	: not more than 0.015 mass%
	S	: not more than 0.003 mass%
	Ni	: 0.1 to 1.5 mass%
	Mo	: 0.15 to 0.60 mass%
30	Nb	: 0.01 to 0.10 mass%
	Ti	: 0.005 to 0.030 mass%
	Al	: not more than 0.06 mass%
	and, one or more of:	
	B	: not more than 0.0025 mass%
35	N	: 0.001 to 0.006 mass%
	V	: not more than 0.10 mass%
	Cu	: not more than 1.0 mass%

Cr : not more than 1.0 mass%
Ca : not more than 0.01 mass%
REM : not more than 0.02 mass%
Mg : not more than 0.006 mass%

5 and the remainder consisting of iron and unavoidable
impurities and having the value P defined below being
between 2.5 and 4.0, in which;
the ratio (Hv-ave)/(Hv-M) between the average Vickers
hardness Hv-ave in the direction of thickness of the base
10 metal and the martensitic hardness Hv-M determined by
carbon content is between 0.8 and 0.9 and the
circumferential tensile strength TS-C is between 900 MPa
and 1100 MPa,

$$P = 2.7C + 0.4Si + Mn + 0.8Cr + 0.45(Ni + Cu) +$$
$$(1 + \beta)Mo - 1 + \beta$$

15 where $\beta = 1$ when $B \geq 3$ ppm and $\beta = 0$ when $B < 3$ ppm
 $Hv-M = 270 + 1300C$

wherein the symbols of elements designate the mass%
of the individual elements.

20 9. Ultra-high-strength linepipe having excellent
low-temperature toughness prepared by seam-welding steel
plate consisting of:

C : 0.03 to 0.07 mass%
Si : not more than 0.6 mass%
25 Mn : 1.5 to 2.5 mass%
P : not more than 0.015 mass%
S : not more than 0.003 mass%
Mo : 0.15 to 0.60 mass%
Nb : 0.01 to 0.10 mass%
30 Ti : 0.005 to 0.030 mass%
Al : not more than 0.10 mass%

and, one or more of:

Ni : 0.1 to 1.5 mass%
B : less than 3 ppm
35 V : not more than 0.10 mass%
Cu : not more than 1.0 mass%
Cr : not more than 1.0 mass%

Ca : not more than 0.01 mass%
REM : not more than 0.02 mass%
Mg : not more than 0.006 mass%

and the remainder consisting of iron and unavoidable
5 impurities and having the value P defined below being
between 2.5 and 4.0, in which;

the ratio $(Hv-ave)/(Hv-M^*)$ between the average Vickers
hardness Hv-ave in the direction of thickness of the base
metal and the martensitic hardness Hv-M* determined by
10 carbon content is between 0.75 and 0.9 and the
circumferential tensile strength TS-C is between 900 MPa
and 1100 MPa,

$$P = 2.7C + 0.4Si + Mn + 0.8Cr + 0.45(Ni + Cu) + \\ Mo - 1$$

15 $Hv-M^* = 290 + 1300C$

wherein the symbols of elements designate the mass%
of the individual elements.

10. Ultra-high-strength linepipe having excellent
low-temperature toughness prepared by seam-welding steel
20 plate consisting of:

C : 0.03 to 0.07 mass%
Si : not more than 0.6 mass%
Mn : 1.5 to 2.5 mass%
P : not more than 0.015 mass%
25 S : not more than 0.003 mass%
Mo : 0.15 to 0.60 mass%
Nb : 0.01 to 0.10 mass%
Ti : 0.005 to 0.030 mass%
Al : not more than 0.10 mass%
30 B : 3 ppm to 0.0025 mass%

and, one or more of:

Ni : 0.1 to 1.5 mass%
N : 0.001 to 0.006 mass%
V : not more than 0.10 mass%
35 Cu : not more than 1.0 mass%
Cr : not more than 1.0 mass%
Ca : not more than 0.01 mass%

REM : not more than 0.02 mass%

Mg : not more than 0.006 mass%

and the remainder consisting of iron and unavoidable impurities and having the value P defined below being

5 between 2.5 and 4.0, in which;

the ratio $(Hv-ave)/(Hv-M^*)$ between the average Vickers hardness Hv-ave in the direction of thickness of the base metal and the martensitic hardness Hv-M* determined by carbon content is between 0.75 and 0.9 and the

10 circumferential tensile strength TS-C is between 900 MPa and 1100 MPa,

$$P = 2.7C + 0.4Si + Mn + 0.8Cr + 0.45(Ni + Cu) + 2Mo$$

$$Hv-M^* = 290 + 1300C$$

15 wherein the symbols of elements designate the mass% of the individual elements.

11. Ultra-high-strength linepipe having excellent low-temperature toughness described in claim 9 or 10 containing:

20 N : 0.001 to 0.006 mass%.

12. Ultra-high-strength linepipe having excellent low-temperature toughness described in claim 11, in which the relationship $Ti - 3.4 N > 0$ is satisfied (wherein the symbols of elements designate the mass% of the individual elements).

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13. Ultra-high-strength linepipe having excellent low-temperature toughness described in any of claims 8 to 12, in which the V-notch Charpy value at -20 °C is not lower than 200J.

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14. Ultra-high-strength linepipe having excellent low-temperature toughness described in any of claims 8 to 13, in which the tensile strength in the longitudinal direction of linepipe is not greater than 0.95 times the tensile strength in the circumferential direction thereof.

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15. A method for manufacturing steel plate for ultra-high-strength linepipe having excellent low-

temperature toughness comprising the steps of:
heating slabs consisting of:

	C	: 0.03 to 0.07 mass%
	Si	: not more than 0.6 mass%
5	Mn	: 1.5 to 2.5 mass%
	P	: not more than 0.015 mass%
	S	: not more than 0.003 mass%
	Mo	: 0.15 to 0.60 mass%
	Nb	: 0.01 to 0.10 mass%
10	Ti	: 0.005 to 0.030 mass%
	Al	: not more than 0.10 mass%
	and, one or more of:	
	Ni	: 0.1 to 1.5 mass%
	B	: less than 3 ppm
15	V	: not more than 0.10 mass%
	Cu	: not more than 1.0 mass%
	Cr	: not more than 1.0 mass%
	Ca	: not more than 0.01 mass%
	REM	: not more than 0.02 mass%
20	Mg	: not more than 0.006 mass%

and the remainder consisting of iron and unavoidable impurities and having the value P defined below being between 2.5 and 4.0 and between 1000 and 1250 °C,

rough rolling in a recrystallizing region,
25 rolling in an unrecrystallization austenitic region at 900 °C or below with a cumulative rolling reduction of not less than 75% and, then,

applying accelerated cooling from the austenitic region so that the center of plate thickness cools to 500
30 °C or below at a rate of 1 to 10 °C/sec.,

$$P = 2.7C + 0.4Si + Mn + 0.8Cr + 0.45(Ni + Cu) + Mo - 1$$

wherein the symbols of elements designate the mass% of the individual elements.

35 16. A method for manufacturing steel plate for ultra-high-strength linepipe having excellent low-

temperature toughness comprising the steps of:

heating slabs consisting of:

	C	: 0.03 to 0.07 mass%
	Si	: not more than 0.6 mass%
5	Mn	: 1.5 to 2.5 mass%
	P	: not more than 0.015 mass%
	S	: not more than 0.003 mass%
	Mo	: 0.15 to 0.60 mass%
	Nb	: 0.01 to 0.10 mass%
10	Ti	: 0.005 to 0.030 mass%
	Al	: not more than 0.10 mass%
	B	: 3 ppm to 0.0025 mass%

and, one or more of:

	Ni	: 0.1 to 1.5 mass%
15	N	: 0.001 to 0.006 mass%
	V	: not more than 0.10 mass%
	Cu	: not more than 1.0 mass%
	Cr	: not more than 1.0 mass%
	Ca	: not more than 0.01 mass%
20	REM	: not more than 0.02 mass%
	Mg	: not more than 0.006 mass%

and the remainder consisting of iron and unavoidable impurities and having the value P defined below being between 2.5 and 4.0 and between 1000 and 1250 °C,

25 rough rolling in a recrystallized region,
rolling in an unrecrystallization austenitic region at 900 °C or below with a cumulative rolling reduction of not less than 75% and, then,

30 applying accelerated cooling from the austenitic region so that the center of plate thickness cools to 500 °C or below at a rate of 1 to 10 °C/sec.,

$$P = 2.7C + 0.4Si + Mn + 0.8Cr + 0.45(Ni + Cu) + 2Mo$$

35 wherein the symbols of elements designate the mass% of the individual elements.

17. A method for manufacturing steel plate for

ultra-high-strength linepipe having excellent low-temperature toughness described in claim 15 or 16, in which slabs also contain

N : 0.001 to 0.006 mass%.

5 18. A method for manufacturing steel plate for ultra-high-strength linepipe having excellent low-temperature toughness described in 17, in which the relationship $Ti - 3.4 N > 0$ is satisfied (wherein the symbols of elements designate the mass% of the individual
10 elements).

19. A method for manufacturing ultra-high-strength linepipe having excellent low-temperature toughness comprising the steps of:

forming a steel plate manufactured by the methods
15 for manufacturing ultra-high-strength steel plate having excellent low-temperature toughness described in any of claims 15 to 18 into a pipe form so that the rolling direction of the steel plate agrees with the longitudinal direction of a pipe to be manufactured, and

20 forming a pipe by seam-welding together the edges thereof.

20. A method for manufacturing ultra-high-strength linepipe having excellent low-temperature toughness comprising the steps of:

25 forming a steel plate manufactured by the methods for manufacturing ultra-high-strength steel plate having excellent low-temperature toughness described in any of claims 15 to 18 into a pipe form by the UO process so that the rolling direction of the steel plate agrees with
30 the longitudinal direction of a pipe to be manufactured,

forming a pipe by joining together the edges thereof by applying submerged-arc welding from both inside and outside, and

expanding the welded pipe.

35 21. A method for manufacturing ultra-high-strength linepipe having excellent low-temperature toughness comprising the steps of:

heating slabs consisting of:

	C	: 0.03 to 0.07 mass%
	Si	: not more than 0.6 mass%
	Mn	: 1.5 to 2.5 mass%
5	P	: not more than 0.015 mass%
	S	: not more than 0.003 mass%
	Ni	: 0.1 to 1.5 mass%
	Mo	: 0.15 to 0.60 mass%
	Nb	: 0.01 to 0.10 mass%
10	Ti	: 0.005 to 0.030 mass%
	Al	: not more than 0.06 mass%

and, one or more of:

	B	: not more than 0.0025 mass%
	N	: 0.001 to 0.006 mass%
15	V	: not more than 0.10 mass%
	Cu	: not more than 1.0 mass%
	Cr	: not more than 1.0 mass%
	Ca	: not more than 0.01 mass%
	REM	: not more than 0.02 mass%
20	Mg	: not more than 0.006 mass%

and the remainder consisting of iron and unavoidable impurities and having the value P defined below being between 2.5 and 4.0 and between 1000 and 1250 °C,

rough rolling in a recrystallized region,
25 rolling in an unrecrystallization austenitic region at 900 °C or below with a cumulative rolling reduction of not less than 75%,

applying accelerated cooling from the austenitic region so that the center of plate thickness cools to 500
30 °C or below at a rate of 1 to 10 °C/sec.,

forming the steel plate thus manufactured into a pipe form so that the rolling direction of the steel plate agrees with the longitudinal direction of a pipe to be manufactured, and

35 forming a pipe by welding together the edges thereof.

$$P = 2.7C + 0.4Si + Mn + 0.8Cr + 0.45(Ni + Cu) + (1 + \beta)Mo - 1 + \beta$$

where $\beta = 1$ when $B \geq 3$ ppm and $\beta = 0$ when $B < 3$ ppm

wherein the symbols of elements designate the mass%
5 of the individual elements.

22. A method for manufacturing ultra-high-strength
linepipe having excellent low-temperature toughness
described in claim 21, which furthermore comprising the
steps of:

10 forming the steel plate subjected to accelerated
cooling into a pipe form by the UO process so that the
rolling direction of the steel plate agrees with the
longitudinal direction of a pipe to be manufactured,
joining the edges thereof together by applying
15 submerged-arc welding from both inside and outside, and
expanding the welded pipe.